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GENERATION OF HOLOGRAM-LAMINATE-FILM IMAGES USING RGB RATIO

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Abstract. *We propose a non-photorealistic rendering method for automatically generating hologram-laminate-film (HLF) images from photographic images. The HLF is a transparent laminate film with hologram embossing, and then the HLF images are images obtained by pasting the HLF on photographic images. Our method is implemented by iterative calculation using RGB ratio, and has the effect of preserving edges as well as smoothing photographic images. To verify the effectiveness of our method, we conducted experiments using various photographic images. As a result of the experiment, it was found that the HLF images can be generated by the effect of smoothing that preserves edges.*
Keywords: Non-photorealistic rendering, Hologram-laminate-film, RGB ratio, Automatic generation

1. Introduction.

In recent years, mobile terminals equipped with cameras such as smart phones and tablets have become widespread, and many people can easily take pictures. The photographed images can be easily uploaded to social networking service and websites. When uploading, the photographed images are often converted by image processing [1, 2]. One of these conversions is non-photorealistic rendering (NPR) [3, 4]. NPR transforms photographic images, videos, and three-dimensional models into artistic styles such as painting, drawing, and technical illustration. In addition, NPR methods have been proposed that generate non-photorealistic images drawn on canvas, crepe paper, and concrete wall [5, 6, 7]. The conventional method [5] first samples the pixels of photographic images or videos at random, interpolates between the sampled points, and finally generates canvas-like images on the basis of errors between the interpolated images and photographic images. Concrete-wall-like images [6] are generated using autocorrelation coefficient and inverse filter from photographic images. Crepe-paper-like images [7] are generated using smoothing filter and correlation coefficient from photographic images.

To develop one of NPRs that has never existed, we propose an NPR method for generating HLF images that appear to have the HLF attached to photographic images. The HLF in Figure 1 [8] is a transparent laminate film with hologram embossing, and is directly embossed on the substrate. When the HLF is used, the hologram effect can be easily provided while making use of the design of the adherend. According to our literature surveys, no previous researches have ever studied the generation of the HLF images in NPR. Our method is executed by iteration calculation using RGB ratio, and has the effect of preserving edges as well as smoothing photographic images. To verify the effectiveness of our method, an experiment using various photographic images is performed, and then it is

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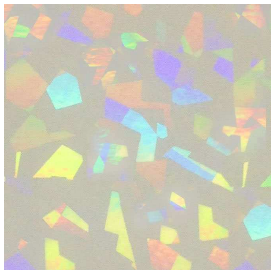


FIGURE 1. Example of HLF

visually confirmed that our method can generate the HLF images by the effect of smoothing that preserves edges. In addition, an experiment is conducted to visually confirm the appearance of the HLF images that change by changing the parameter values.

This paper is organized as follows: the second section describes our method for generating the HLF images, the third section shows experimental results and reveals the effectiveness of our method, and the conclusion of this paper is given in the fourth section.

2. **Our Method.** Our method transforms photographic images by iterative calculation using RGB ratio. The value of the parameter used in the transformation is calculated by using an optimization method. A flow chart of our method is shown in Figure 2.

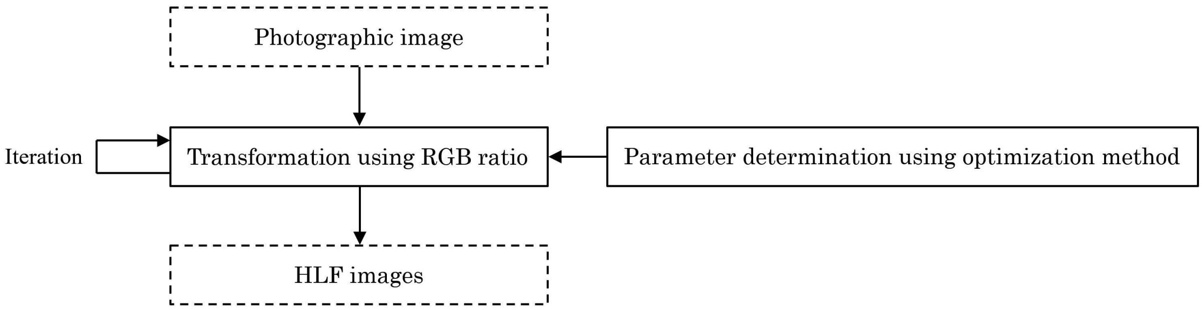


FIGURE 2. Flow chart of our method

The input pixel values (R, G, B) for the spatial coordinates (i, j) $(i = 1, 2, \ldots, I; j = 1, 2, \ldots, J)$ of a photographic image are denoted by $f_{R,i,j}$, $f_{G,i,j}$, and $f_{B,i,j}$, respectively. The pixel values $f_{R,i,j}$, $f_{G,i,j}$, and $f_{B,i,j}$ have value of U gradation from 0 to $U - 1$.

The output pixel values $f^{(t)}_{R,i,j}$, $f^{(t)}_{G,i,j}$, and $f^{(t)}_{B,i,j}$ are calculated in the following equations:

$$f^{(t)}_{R,i,j} = a^{(t-1)}_{i,j} \frac{f^{(t-1)}_{R,i,j}}{F^{(t-1)}_{i,j}} \tag{1}$$

$$f^{(t)}_{G,i,j} = a^{(t-1)}_{i,j} \frac{f^{(t-1)}_{G,i,j}}{F^{(t-1)}_{i,j}} \tag{2}$$

$$f^{(t)}_{B,i,j} = a^{(t-1)}_{i,j} \frac{f^{(t-1)}_{B,i,j}}{F^{(t-1)}_{i,j}} \tag{3}$$

$$F^{(t-1)}_{i,j} = f^{(t-1)}_{R,i,j} + f^{(t-1)}_{G,i,j} + f^{(t-1)}_{B,i,j} \tag{4}$$

where t $(= 1, 2, \ldots)$ is an iteration number, $f^{(0)}_{R,i,j} = f_{R,i,j}$, $f^{(0)}_{G,i,j} = f_{G,i,j}$, $f^{(0)}_{B,i,j} = f_{B,i,j}$, and $a^{(t-1)}_{i,j}$ is a real number used in the tth calculation. If $f^{(t)}_{R,i,j}$, $f^{(t)}_{G,i,j}$, and $f^{(t)}_{B,i,j}$ are less than 0, then $f^{(t)}_{R,i,j}$, $f^{(t)}_{G,i,j}$, and $f^{(t)}_{B,i,j}$ must be set to 0, respectively. If $f^{(t)}_{R,i,j}$, $f^{(t)}_{G,i,j}$, and $f^{(t)}_{B,i,j}$ are greater than $U-1$, then $f_{R,i,j}^{(t)}$, $f_{G,i,j}^{(t)}$, and $f_{B,i,j}^{(t)}$ must be set to $U-1$, respectively. The processing is repeated T times, and then an image composed of the pixel values $f_{R,i,j}^{(T)}$, $f_{G,i,j}^{(T)}$, and $f_{B,i,j}^{(T)}$ is the HLF image of our method.

The variable $a_{i,j}^{(t-1)}$ is calculated using the values of the pixels contained in the window, and has a relationship represented in the following equation:

$$\min_{a_{i,j}^{(t-1)}} \sum_{k=i-W}^{i+W} \sum_{l=j-W}^{j+W} \left\{ \left(f_{R,k,l}^{(t-1)} - a_{i,j}^{(t-1)} \frac{f_{R,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \right)^2 + \left(f_{G,k,l}^{(t-1)} - a_{i,j}^{(t-1)} \frac{f_{G,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \right)^2 + \left(f_{B,k,l}^{(t-1)} - a_{i,j}^{(t-1)} \frac{f_{B,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \right)^2 \right\} \quad (5)$$

where W is the window size, and k and l are the positions in the window. Equation (5) is solved by differentiating with $a_{i,j}^{(t-1)}$ and setting equal zero.

$$\sum_{k=i-W}^{i+W} \sum_{l=j-W}^{j+W} \left\{ \frac{f_{R,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \left(f_{R,k,l}^{(t-1)} - a_{i,j}^{(t-1)} \frac{f_{R,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \right) + \frac{f_{G,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \left(f_{G,k,l}^{(t-1)} - a_{i,j}^{(t-1)} \frac{f_{G,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \right) + \frac{f_{B,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \left(f_{B,k,l}^{(t-1)} - a_{i,j}^{(t-1)} \frac{f_{B,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \right) \right\} = 0 \quad (6)$$

When Equation (6) is converted, Equation (7) is obtained.

$$a_{i,j}^{(t-1)} = \frac{\sum_{k=i-W}^{i+W} \sum_{l=j-W}^{j+W} \frac{{f_{R,k,l}^{(t-1)}}^2 + {f_{G,k,l}^{(t-1)}}^2 + {f_{B,k,l}^{(t-1)}}^2}{F_{k,l}^{(t-1)}}}{\sum_{k=i-W}^{i+W} \sum_{l=j-W}^{j+W} \left\{ \left(\frac{f_{R,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \right)^2 + \left(\frac{f_{G,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \right)^2 + \left(\frac{f_{B,k,l}^{(t-1)}}{F_{k,l}^{(t-1)}} \right)^2 \right\}} \quad (7)$$

3. **Experiments.** Two experiments were conducted to verify the effectiveness of our method: the first experiment changed the values of the parameters T and W to visually confirm the HLF patterns using Lenna image in Figure 3, and the second experiment applied our method to various photographic images in Figure 4 to visually confirm that the HLF images are smoothed with the edges preserved. All images used in the experiments comprised $512 * 512$ pixels and 256 gradations.

FIGURE 3. Lenna image

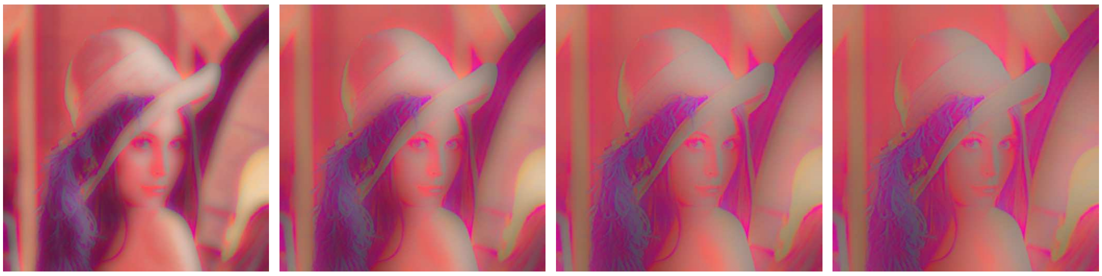
FIGURE 4. Various photographic images

HLF images by changing the value of the parameter T were visually confirmed using the Lenna image. The value of the parameter T was set to 10, 30, 50, and 70. The value of the parameter W was set to 6. The HLF images generated by changing the value of the parameter T are shown in Figure 5. As the value of the parameter T increased, the smoothing progressed while the edges were preserved. When the value of the parameter T was 50 or more, the HLF images hardly changed.

(a) $T = 10$ (b) $T = 30$ (c) $T = 50$ (d) $T = 70$

FIGURE 5. HLF images in the case of $T = 10$, 30, 50 and 70

HLF images by changing the value of the parameter W were visually confirmed using the Lenna image. The value of the parameter W was set to 3, 6, 9, and 12. The value of the parameter T was set to 50. The HLF images generated by changing the value of the parameter W are shown in Figure 6. As the value of the parameter W was smaller, details of the Lenna image could be expressed, but the smoothing effect was smaller. The value of the parameter W may be changed according to the purpose of use of the user.



(a) $W = 3$ (b) $W = 6$ (c) $W = 9$ (d) $W = 12$

FIGURE 6. HLF images in the case of $W = 3$, 6, 9 and 12

Our method was applied to eight photographic images. The values of the parameters T and W were set to 50 and 6 with reference to the result of the previous experiments, respectively. The eight HLF images generated by our method are shown in Figure 7. All HLF images were smoothed while preserving the main edges. Then, all HLF images have different representations from the non-photorealistic images drawn on canvas, crepe paper, and concrete wall by the conventional methods [5, 6, 7].

4. **Conclusions.** We proposed a method for automatically generating HLF images from photographic images by iteration calculation using RGB ratio. We conducted two experiments to verify the effectiveness of the proposed method: the first experiment changed the parameter values to visually confirm the HLF patterns using the Lenna image, and the second experiment applied our method to various photographic images to visually confirm that the HLF images were smoothed with the edges preserved. As a result of experiments, it was clarified that the HLF images can be generated by using our method, and how the HLF images change according to the change in the parameter values of our method.

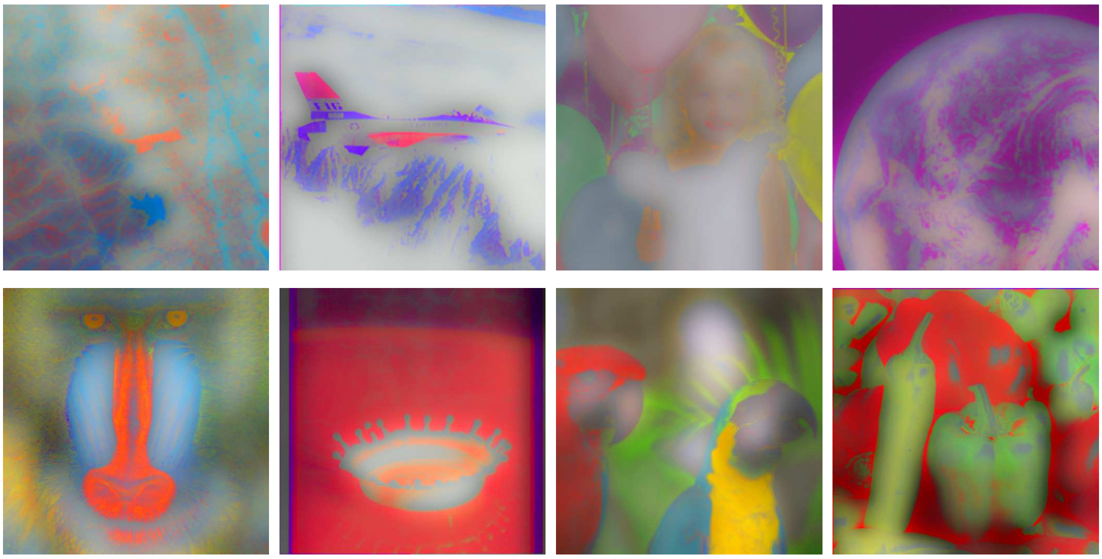


Figure 7. HLF images generated from various photographic images

In future work, we will try to apply our method to videos and three-dimensional data.

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